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A Parallel Processing Algorithm for Gravity Inversion

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The paper presents results of using MPI parallel processing for the 3D inversion of gravity anomalies. The work is done under the FP7 project HP-SEE (http://www.hp-see.eu/). The inversion of geophysical anomalies remains a challenge, and the use of parallel processing can be a tool to achieve better results, “compensating” the complexity of the ill-posed problem of inversion with the increase of volume of calculations. We considered the gravity as the simplest case of physical fields and experimented an algorithm based in the methodology known as CLEAN and developed by Högbom in 1974. The 3D geosection was discretized in finite cuboid elements and represented by a 3D array of nodes, while the ground surface where the anomaly is observed as a 2D array of points. Starting from a geosection with mass density zero in all nodes, iteratively the algorithm defines the 3D node that offers the best anomaly shape that approximates the observed anomaly minimizing the least squares error; the mass density in the best 3D node is modified with a prefixed density step and the related effect subtracted from the observed anomaly; the process continues until some criteria is fulfilled.

Theoretical complexity of he algorithm was evaluated on the basis of iterations and run-time for a geosection discretized in different scales. We considered the average number N of nodes in one edge of the 3D array. The order of number of iterations was evaluated O(N3); and the order of run-time was evaluated O(N8). We used several different methods for the identification of the 3D node which effect offers the best least squares error in approximating the observed anomaly: unweighted least squares error for the whole 2D array of anomalous points; weighting least squares error by the inverted value of observed anomaly over each 3D node; and limiting the area of 2D anomalous points where least squares are calculated over shallow 3D nodes. By comparing results from the inversion of single body and two-bodies geosections, it was concluded that limitation of weighted least squares error gave better results in all cases, at the range of 3% - 6%. The typical used geosection was 4000m*4000m*2000m discretized with 11x11x6, 21x21x11 and 41x41x21 of 3D nodes. Bodies were represented by vertical prisms with section 400m*400m and different heights.

The run-time of the single body geosection resulted up to several hours for a single processor computer for the geosection with 41x41x21 nodes. Parallel processing with OpenMP and MPI was used for geosections of 81x81x41 nodes (using finite cuboid elements with edge size 50m) in parallel systems of Bulgarian Academy of Sciences and of Super Computing Center of NIIFI in Hungary. Using up to 1,000 processors the run-time resulted about 24 hours, and it was evaluated that for a 3D array of 161x161x81 nodes (cuboids with edge 25m) the run time in 1,000 cores would be up to one year.

The quality of inverted geosections resulted good in case of single body models, the algorithm offered clear contrast between the mass density of the body and the environment, and the shapes of original and inverted prisms resulted quite similar. In two body cases better solutions were obtained for shallow bodies, with the depth the tendency of the algorithm was to delineate only the shallow tops of prisms and compensate with a single mass at the depth. The algorithm was tested also with two real cases of typical gravity anomalies observed in Albanides.